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AD NUMBER
AD028691
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TO: unclassified
FROM: secret
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Controlling DoD Organization: Army Armament Research and Development Command, Dover, NJ.
AUTHORITY
ARRADCOM ltr dtd 4 Sep 1981; ARRADCOM ltr dtd 4 Sep 1981

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DUPLICATE

THE FIRESTONE TIRE & RUBBER COMPANY

105 MM. BATTALION ANTI-TANK PROJECT

~~Robert~~
~~James~~ *Mc*
Jackson - file.

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MAY 1952

SECURITY INFORMATION

SECRET
SUPPLEMENT TO
TWENTY-SECOND
PROGRESS REPORT
OF
THE FIRESTONE TIRE & RUBBER CO.
ON
105 MM BATTALION ANTI-TANK PROJECT

Contract No.
DA-33-019-ORD-33 (Negotiated)
RAD ORDTs 1-12383

THE FIRESTONE TIRE & RUBBER CO.
Defense Research Division
Akron, Ohio
MAY, 1952

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S E C R E T

ABSTRACT

Three series of serrated liners, totaling seventy-six rounds were tested for penetration into mild steel at various spin rates. The inspection data, penetration data and test conditions are presented and the test results are discussed. The three series of liners tested were as follows: (1) 45-degree copper cones with 100 flat pressed exterior flutes (2) 45-degree copper cones with 4 curved flutes pressed into the exterior surface, and (3) 45-degree copper cones with 50 flat flutes machined into the exterior surface.

A future program for serrated liners and double-body projectiles is presented.

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T-120 PROJECTILE

Serrated Liners

Three series of serrated liners, totaling seventy-six rounds, were tested for penetration into mild steel at various spin rates. A standoff distance of 7.5 inches was used.

The liner designs, DRD 254 No. 1, DRD 263-1 and DRD 272 No. 1 are shown in Figures 1 to 3 inclusive. The inspection data are recorded in Tables I to III and the penetration data are shown in Tables IV to VI and in Figures 4 to 6.

DRD 254 No. 1 Liners

The DRD 254 No. 1 liners have 100 flat flutes pressed into the exterior surface of 45° copper cones. Flute depth varies linearly from $.0422 \pm .0016$ inch at the lower datum .484 inch above the base to $.0087 \pm .0005$ inch at the upper datum, 2.875 inches above the base. The average wall thickness, measured from the crest of the flute to the inside surface, is $.1517 \pm .0019$ inch at the lower datum and $.1603 \pm .0022$ inch at the upper datum. This series of fluted liners differs in one important respect from all other series of liners in that the offset surface is as nearly radial as could be obtained. In the other series this surface has been inclined 30° to the radius vector through the root of the flute. With smaller numbers of flutes the projected area of the offset surface is a small portion of the total conical surface, and has been considered negligible, but with a large number of flutes, such as the 100 used here, the projected area would approximate 30% of the total surface and probably should not be neglected. Accordingly, to be sure that the effect measured is preponderantly the effect of the canted surface, a radial offset surface was specified for these 100-flute liners.

The average penetration at the peak

in the penetration curve is 15.0 inches of mild steel at 20 rev/sec. This penetration represents approximately 84% of the non-rotated penetration of a smooth liner with a .100-inch wall and is approximately 100% of the non-rotated penetration of a smooth liner with a .150-inch wall. At spin rates between 15 and 90 rev/sec these liners are slightly superior to smooth liners of either wall thickness.

DRD 263-1 Liners

The DRD 263-1 liners have four curved flutes pressed into the exterior surface of 45° copper cones. Flute depth varies linearly from $.0614 \pm .0004$ inch at the lower datum plane .484 inch above the base to $.0219 \pm .0005$ inch at the upper datum 2.875 inches above the base. The average wall thickness, measured from the crest of the flutes, tapers from $.1564 \pm .0019$ inch at the lower datum to $.1247 \pm .0026$ inch at the upper datum. The minimum wall thickness is, therefore, reasonably constant, and varies only from .0950 to .1028 inch. The average penetration at the peak of the penetration curve is 8.0 inches at 0 rev/sec. This design did not result in any measurable shift in the optimum spin rate and the penetration efficiency is only 45% that of smooth liners of .100-inch wall and 53% that of smooth .150-inch wall liners. These liners are substantially inferior to smooth cones at all spin rates.

DRD 272 No. 1 Liners

The DRD 272 No. 1 liners have 50 flat flutes machined into the exterior surface of a 45° copper cone. Flute depth varies linearly from $.0611 \pm .0010$ inch at a lower datum plane .484 inch above the base to $.0211 \pm .0010$ inch at an upper datum plane 2.90 inches above the base. The average wall thickness, measured from the crest of the flutes, tapers from .1615

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$\pm .0018$ inch at the lower datum to $.1272 \pm .0019$ inch at the upper datum. The minimum wall thickness varies from $.1004$ to $.1061$ inch. The average penetration at the peak of the penetration curve is 11.4 inches and occurs at 50 rev/sec. This is about 63% of the non-rotated penetration of a smooth liner with a $.100$ -inch wall, and is approximately 76% of the non-rotated penetration of a smooth liner with an average wall of $.150$ inch. These liners are slightly better than unfluted smooth cones at spin rates between 40 and 60 rev/sec. At other spin rates smooth liners are superior.

Discussion

A correlation of the performance of

nine series of serrated liners with design parameters was presented in the Supplement to the Sixteenth Progress Report. In subsequent reports data for additional series of liners have been presented. The data presented in this report permit the extension of the correlation upward to 100 flutes and downward to 4 flutes. Figure 7 is a plot of the revised correlation. The correlation fails to account for the behavior of only one series, the DRD 272 No. 1 cones with 50 deep flutes. These cones behave as might be expected if their flute depth was only $.018$ or $.020$ inch deep. Accordingly it will be necessary to study the effect of flute depth more extensively to determine with greater certainty the nature of this relationship.

Future Program

1. Serrated Liners

a. DRD 267, 60 flat flutes pressed on exterior surface only, $.0107$ in. nominal depth, $.100$ -inch wall, 42° copper cone. These liners are ready for loading.

b. DRD 267, same as a except aluminum cones are to be made.

c. DRD 318, 36 flutes pressed into interior surface only, $.010$ in. nominal flute depth, $.100$ -inch wall thickness (42° copper cone).

d. DRD 319, 45 flutes but otherwise similar to c.

e. DRD 320 (a), 60 flutes but otherwise similar to c.

f. DRD 320 (b), similar to e except flute depth is $.020$ in.

g. DRD 320 (c), similar to e except

flute depth is $.040$ in.

h. DRD 321, 100 flutes but otherwise similar to c.

i. DRD 78 modified by change of indexing. 16 curved flutes, internal and external, with an indexing angle of 5° . Nominal flute depth is $.030$ inch, wall thickness is $.100$ inch.

2. Double Body Projectiles

Firing tests with test slugs to determine muzzle spin rate are planned for the following bearing designs:

a. DRA 218 and DRA 216-219 of varying hardness.

b. DRA 218 with four different "Foscoat" treatments on bearing surfaces.

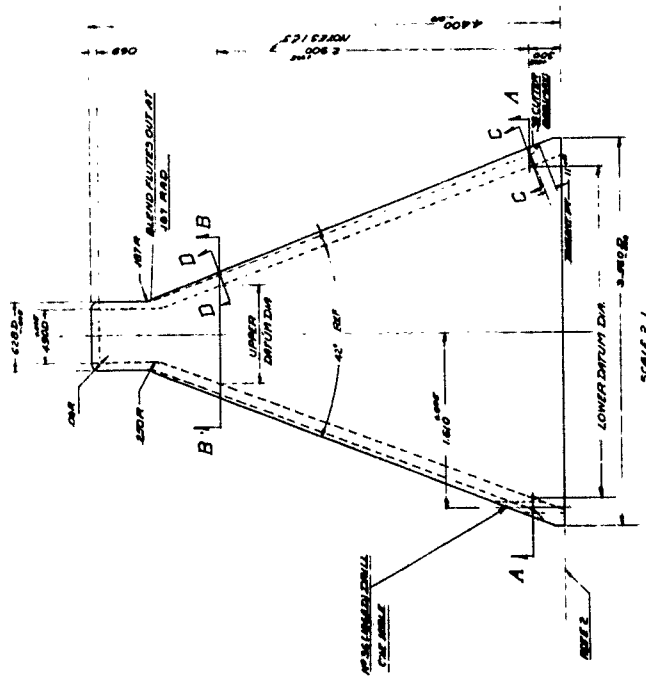
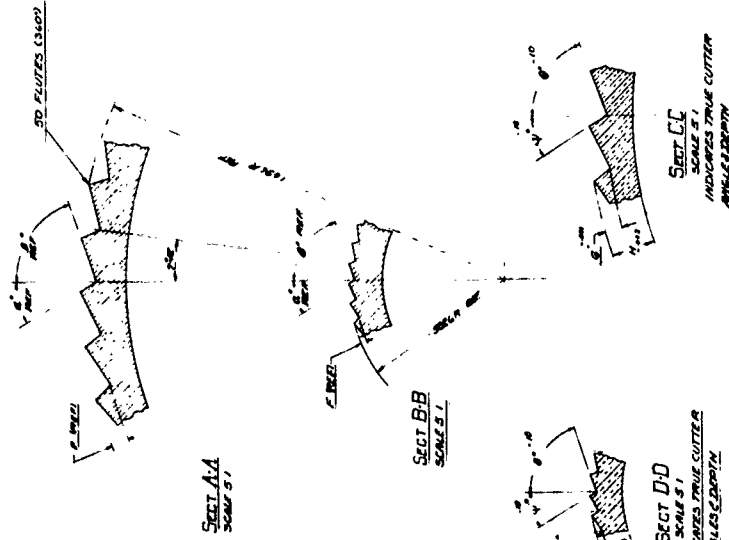
c. DRC 389 deep groove combination radial and thrust ball bearings without a cage.

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DESIGN	REMARKS	DATE
100	100	100
101	101	101
102	102	102
103	103	103
104	104	104
105	105	105
106	106	106
107	107	107
108	108	108
109	109	109
110	110	110
111	111	111
112	112	112
113	113	113
114	114	114
115	115	115
116	116	116
117	117	117
118	118	118
119	119	119
120	120	120



NOTE:
ALL FLUTE CORNERS TO BE CONCENTRIC WITHIN .003 IN. WITH RESPECT TO 3.250 RADIUS. DIA.
INDICATED SURFACE TO BE PERPENDICULAR WITHIN .001 IN. OF PART. WITHIN .001 IN. OF
SURFACE. ANY VARIATION IN PERPENDICULARITY OR THICKNESS OF WALL SHALL NOT EXCEED .003 IN. ANY PARTIAL PLANE.
OR IN ANY TRANSVERSE PLANE. WALL THICKNESS SHALL NOT EXCEED .001 IN. CORNERS OR ROOTS OF FLUTES
4. FINISH

Fig. 3. Serrated Liner Design, 50 Flat Flutes.
Firstone Drawing No. DRD 272 No. 1.

S E C R E T

Table I
Inspection Data For DRD 254 No. 1 Liners
100 Flat Flutes

Liner No.	Ave. Flute Depth-in.		Std.Dev. Flute Depth-in.		Wall Thickness-in.		Concentricity ² -in.	
	Lower Datum ¹	Upper Datum	Lower Datum	Upper Datum	Lower Datum	Upper Datum	Lower Datum	Upper Datum
DRD254 No. 1	.0437	.0160			.1450	.1450	.0030	.0030
P100-1 ³	.0404	.0077	±.0014	±.0011	.1558	.1598	.0050	.0015
P100-2	.0413	.0081	±.0008	±.0008	.1502	.1556	.0040	.0020
P100-3	.0421	.0088	±.0012	±.0009	.1518	.1580	.0030	.0020
P100-4	.0430	.0088	±.0004	±.0010	.1525	.1585	.0035	.0030
P100-5	.0430	.0083	±.0006	±.0013	.1530	.1625	.0030	.0030
P100-6	.0422	.0072	±.0006	±.0008	.1542	.1608	.0025	.0025
P100-7	.0402	.0096	±.0004	±.0007	.1502	.1610	.0030	.0050
P100-8	.0405	.0086	±.0006	±.0011	.1510	.1608	.0020	.0020
P100-9	.0447	.0088	±.0009	±.0011	.1512	.1558	.0020	.0020
P100-10	.0417	.0085	±.0007	±.0009	.1520	.1628	.0030	.0040
P100-11	.0455	.0092	±.0008	±.0010	.1552	.1625	.0030	.0030
P100-12	.0455	.0088	±.0012	±.0009	.1530	.1570	.0030	.0030
P100-13	.0414	.0084	±.0008	±.0011	.1530	.1600	.0025	.0030
P100-14	.0443	.0089	±.0017	±.0008	.1532	.1588	.0030	.0030
P100-15	.0436	.0086	±.0009	±.0009	.1515	.1635	.0025	.0025
P100-16	.0415	.0086	±.0011	±.0008	.1495	.1582	.0015	.0020
P100-17	.0420	.0080	±.0008	±.0007	.1530	.1630	.0030	.0030
P100-18	.0403	.0088	±.0006	±.0011	.1478	.1598	.0020	.0020
P100-19	.0416	.0088	±.0011	±.0010	.1498	.1620	.0020	.0020
P100-20	.0412	.0090	±.0009	±.0008	.1492	.1598	.0020	.0020
P100-21	.0436	.0094	±.0008	±.0007	.1522	.1630	.0020	.0020
P100-22	.0400	.0093	±.0014	±.0009	.1482	.1615	.0020	.0020
P100-23	.0440	.0086	±.0011	±.0010	.1530	.1610	.0020	.0020
P100-24	.0402	.0093	±.0010	±.0008	.1502	.1620	.0020	.0020
P100-25	.0423	.0085	±.0014	±.0005	.1518	.1612	.0030	.0030
Average	.0422	.0087			.1517	.1603	.0027	.0025
St'd. Dev.	±.0016	±.0005			±.0019	±.0022	±.0008	±.0008

Notes:

1. Lower datum is .484 inch above the base; upper datum 2.875 inches above the base.
2. The indicated measurement at each datum is the total indicator runout of the liner's outside surface relative to the register diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.
3. Held for sectioning and display.

Table II
Inspection Data For DRD 263-1 Liners
4 Curved Flutes

Liner No.	Average Flute Depth - inches			Wall Thickness - in.			Concentricity ² - in.			Datum Dia. - inches Crest to Crest		
	A	B	C	A	B	C	A	B	C	A	B	C
DRD263-1	.0563	.0370	.0194	.1550	.1360	.1188	.0030	.0030	.0030	3.303	2.035	1.085
P4-1	.0612	.0402	.0220	.1592	.1408	.1266	.0045	.0025	.0020			
P4-2	.0618	.0405	.0216	.1558	.1422	.1271	.0015	.0010	.0040			
P4-3	.0616	.0410	.0224	.1558	.1415	.1264	.0020	.0030	.0040			
P4-4	.0614	.0410	.0220	.1525	.1395	.1210	.0020	.0010	.0010			
P4-5	.0619	.0412	.0221	.1566	.1422	.1225	.0020	.0020	.0030			
P4-6	.0608	.0410	.0218	.1545	.1428	.1252	.0030	.0010	.0040			
P4-7	.0612	.0410	.0222	.1560	.1435	.1250	.0020	.0010	.0030	3.141	2.048	1.106
P4-8	.0612	.0410	.0215	.1545	.1425	.1236	.0020	.0020	.0020			
P4-9	.0612	.0408	.0222	.1558	.1406	.1204	.0010	.0030	.0050			
P4-10	.0616	.0416	.0225	.1572	.1444	.1222	.0010	.0020	.0040			
P4-11	.0612	.0415	.0222	.1558	.1412	.1228	.0045	.0030	.0050	3.141	2.050	1.106
P4-12	.0612	.0412	.0221	.1581	.1454	.1234	.0010	.0015	.0045			
P4-13	.0615	.0416	.0219	.1564	.1412	.1189	.0010	.0015	.0020			
P4-14	.0615	.0407	.0215	.1548	.1412	.1265	.0030	.0030	.0030			
P4-15	.0616	.0410	.0224	.1574	.1420	.1232	.0030	.0030	.0045			
P4-16	.0611	.0406	.0216	.1520	.1410	.1279	.0040	.0025	.0005			
P4-17	.0618	.0415	.0216	.1560	.1424	.1288	.0040	.0030	.0025	3.134	2.061	1.128
P4-18	.0610	.0409	.0214	.1579	.1429	.1231	.0020	.0020	.0015			
P4-19	.0618	.0416	.0219	.1582	.1420	.1275	.0010	.0015	.0000	3.115	2.065	1.098
P4-20	.0611	.0402	.0211	.1584	.1392	.1241	.0000	.0020	.0005			
P4-21	.0610	.0405	.0206	.1641	.1448	.1260	.0000	.0030	.0050			
P4-22	.0609	.0405	.0216	.1594	.1452	.1300	.0020	.0050	.0050	3.125	2.054	1.097
P4-23	.0615	.0420	.0225	.1570	.1425	.1249	.0030	.0000	.0000			
P4-24	.0616	.0410	.0226	.1536	.1395	.1236	.0020	.0015	.0010			
P4-25	.0622	.0412	.0214	.1562	.1431	.1231	.0030	.0020	.0060	3.150	2.072	1.104
P4-26	.0618	.0412	.0221	.1550	.1420	.1260	.0030	.0020	.0020	3.134	2.069	1.097
P4-27 ³	.0612	.0414	.0216	.1575	.1428	.1282	.0040	.0030	.0015	3.152	2.077	1.135
P4-28 ³	.0604	.0416	.0216	.1526	.1379	.1229	.0020	.0050	.0060			
Average	.0614	.0411	.0219	.1564	.1420	.1247	.0023	.0023	.0028	3.136	2.062	1.109
Std. Dev.	±.0004	±.0005	±.0005	±.0019	±.0018	±.0026	±.0011	±.0011	±.0018			

Notes:

- Inspection data are presented for three datum planes: A, .484 inch above the base; B, 1.750 inches above the base; C, 2.875 inches above the base.
- The indicated measurement at each datum is the total indicator runout of the liner's outside surface relative to the register diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.
- Held for sectioning and display.

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Table III
Inspection Data For DRD 272 No. 1 Liners
50 Flat Flutes

Liner No.	Ave.Flute Depth ¹ - in.		Wall Thickness-in.		Concentricity ² -in.		Datum Dia.-in. Crest to Crest	
	Lower Datum	Upper Datum	Lower Datum	Upper Datum	Lower Datum	Upper Datum	Lower Datum	Upper Datum
DRD272	.0630	.0226	.1610	.1220	.0030	.0030	3.234	1.165
P50-1	.0608	.0206	.1598	.1269	.0015	.0030	3.258	1.179
P50-2	.0611	.0214	.1602	.1268	.0035	.0045	3.256	1.178
P50-3	.0612	.0207	.1628	.1259	.0030	.0050	3.256	1.183
P50-4	.0615	.0212	.1628	.1272	.0025	.0025	3.244	1.188
P50-5	.0610	.0203	.1615	.1259	.0030	.0030	3.256	1.188
P50-6	.0616	.0203	.1630	.1265	.0020	.0010	3.256	1.188
P50-7	.0611	.0197	.1629	.1286	.0035	.0030	3.260	1.190
P50-8	.0606	.0200	.1626	.1274	.0015	.0020	3.253	1.192
P50-9	.0600	.0205	.1591	.1268	.0050	.0035	3.253	1.183
P50-10	.0608	.0220	.1621	.1271	.0010	.0045	3.252	1.181
P50-11	.0628	.0230	.1640	.1273	.0020	.0020	3.242	1.191
P50-12	.0613	.0207	.1618	.1275	.0020	.0040	3.258	1.178
P50-13	.0616	.0228	.1622	.1281	.0010	.0005	3.257	1.198
P50-14	.0643	.0230	.1610	.1255	.0030	.0025	3.256	1.174
P50-15	.0612	.0211	.1632	.1282	.0020	.0010	3.256	1.188
P50-16	.0601	.0208	.1608	.1252	.0025	.0020	3.251	1.179
P50-17	.0617	.0213	.1626	.1289	.0005	.0030	3.251	1.176
P50-18	.0600	.0206	.1592	.1280	.0020	.0030	3.252	1.185
P50-19	.0603	.0189	.1579	.1198	.0020	.0030	3.258	1.179
P50-20	.0617	.0218	.1621	.1272	.0020	.0020	3.258	1.183
P50-21	.0616	.0212	.1632	.1282	.0030	.0040	3.261	1.191
P50-22	.0609	.0200	.1642	.1300	.0010	.0030	3.260	1.198
P50-23	.0618	.0211	.1628	.1270	.0020	.0030	3.253	1.180
P50-24	.0618	.0231	.1609	.1276	.0020	.0030	3.257	1.190
P50-25	.0598	.0201	.1565	.1286	.0010	.0040	3.255	1.180
P50-26	.0610	.0217	.1628	.1274	.0045	.0035	3.255	1.188
P50-27 ³	.0605	.0212	.1606	.1280	.0025	.0025	3.258	1.195
P50-28 ³	.0600	.0209	.1608	.1253	.0025	.0010	3.241	1.184
P50-29 ³	.0602	.0206	.1614	.1313	.0015	.0030	3.255	1.185
Average	.0611	.0211	.1615	.1272	.0023	.0028	3.254	1.185
Std. Dev.	±.0010	±.0010	±.0018	±.0019	±.0010	±.0010	±.005	±.006

Notes:

1. Lower datum is .484 inch above the base; upper datum 2.900 inches above the base.
2. The indicated measurement at each datum is the total indicator runout of the liner's outside surface relative to the register diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.
3. Held for sectioning and display.

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Table IV
Penetration Data For DRD 254 No. 1 Liners
100 Flat Flutes
 See Fig. 4

Round No.	Pounds Comp B	Rev/Sec	Penetration (inches M.S.)	Max. Spread (inches)	Std. Deviation (inches)
P100-18 P100-19 P100-20	2.50 2.52 2.51	-15 " "	9.62 9.81 9.88 Avg. <u>9.77</u>	.26	±.14
P100-8 P100-9 P100-10	2.48 2.48 2.48	0 " "	14.00 14.69 13.81 Avg. <u>14.17</u>	.88	±.47
P100-11 P100-12 P100-13 P100-24	2.50 2.44 2.44 2.50	15 " " "	14.94 14.62 15.00 15.18 Avg. <u>14.94</u>	.56	±.24
P100-17 P100-21 P100-22 P100-25	2.52 2.50 2.48 2.50	20 " " "	14.94 14.50 14.06 14.56 Avg. <u>14.52</u>	.88	±.36
P100-14 P100-15 P100-16 P100-23	2.50 2.54 2.54 2.50	30 " " "	15.25 14.38 14.18 15.12 Avg. <u>14.73</u>	1.07	±.53
P100-5 P100-6 P100-7	2.62 2.50 2.50	45 " "	13.00 12.75 10.18 Avg. <u>11.98</u>	2.78	±1.56
P100-2 P100-3 P100-4	2.54 2.60 2.58	90 " "	6.81 6.56 6.94 Avg. <u>6.77</u>	.38	±.20

Notes:

1. Standoff distance was 7.5 inches in each case.
2. Rounds loaded at Ravenna Arsenal with Comp. B from Holston Lot 3-126.
3. DRC 15-8 test assemblies were used.

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Table V
Penetration Data For DRD 263-1 Liners
4 Curved Flutes
 See Fig. 5

Round	Pounds Comp B	Rev/Sec	Penetration (Inches M.S)	Max. Spread (inches)	Std.Deviation (inches)
P4-11 P4-12	2.46 2.48	-180 "	3.44 4.44 <u>3.94</u>	1.00	—
P4-8 P4-9 P4-24	2.44 2.48 2.46	-45 " "	6.38 5.18 6.25 Avg. <u>5.94</u>	1.20	±.65
P4-19 P4-20 P4-21 P4-25	2.40 2.48 2.36 2.34	-30 " " "	7.18 6.81 9.75 6.12 Avg. <u>7.46</u>	3.63	±1.59
P4-1 P4-2 P4-3	2.50 2.36 2.44	0 " "	8.38 6.31 8.62 Avg. <u>7.77</u>	2.31	±1.27
P4-16 P4-17 P4-18 P4-26	2.40 2.46 2.46 2.46	+30 " " "	10.81 6.25 6.69 7.25 Avg. <u>7.75</u>	4.56	±2.08
P4-7 P4-22 P4-23	2.54 2.32 2.46	+45 " "	5.94 6.69 5.44 Avg. <u>6.02</u>	1.25	±.63
P4-4 P4-5 P4-6	2.54 2.46 2.46	+90 " "	2.88 4.06 2.75 Avg. <u>3.23</u>	1.31	±.72
P4-10	2.44	+180	2.81		
P4-13 P4-14	2.48 2.36	+240 "	2.50 2.31 Avg. <u>2.40</u>	.19	—
Notes: 1. Standoff distance was 7.5 inches in each case. 2. All rounds were loaded at Ravenna Arsenal with Comp B from Holston Lot 3-126. 3. DRC 15-10 test assemblies were used. 4. Round P4-15 was accidentally damaged and was subsequently destroyed.					

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Table VI
Penetration Data For DRD 272 No. 1 Liners
50 Flat Flutes
 See Fig. 6

Round No.	Pounds Comp B	Rev/Sec	Penetration (inches M.S.)	Max. Spread (inches)	Std. Deviation (inches)
P50-10 P50-11 P50-12	2.62 2.46 2.52	-90 " "	3.31 3.12 4.00 Avg. <u>3.48</u>	.88	±.47
P50-1 P50-2 P50-3	2.52 2.50 2.48	0 " "	6.94 7.50 6.12 Avg. <u>6.85</u>	1.38	±.70
P50-17 P50-18 P50-19	2.56 2.42 2.56	30 " "	8.44 8.18 10.18 Avg. <u>8.93</u>	2.00	±1.09
P50-13 P50-14 P50-15 P50-16 P50-26	2.50 2.52 2.52 2.52 2.50	45 " " " "	Low Order 11.25 14.31 9.56 8.06 Avg. <u>10.80</u>	6.25	±2.68
P50-23 P50-24 P50-25	2.52 2.52 2.52	50 " "	10.25 12.12 11.38 Avg. <u>11.25</u>	1.87	±.94
P50-20 P50-21 P50-22	2.50 2.48 2.52	60 " "	10.69 7.88 10.81 Avg. <u>9.79</u>	2.93	±1.66
P50-4 P50-5 P50-8	2.50 2.48 2.54	90 " "	5.62 4.56 5.38 Avg. <u>5.19</u>	1.06	±.56
P50-6 P50-7 P50-9	2.54 2.50 2.51	180 " "	3.62 3.69 3.25 Avg. <u>3.52</u>	.44	±.24

Notes:

1. Standoff distance was 7.5 inches in each case.
2. Rounds loaded at Ravenna Arsenal with Comp. B from Holston Lot 3-126.
3. DRC376 test assemblies were used.
4. Detonators and boosters were placed in DRB 262-1 dummy base elements and inserted in molded cavity in charge.

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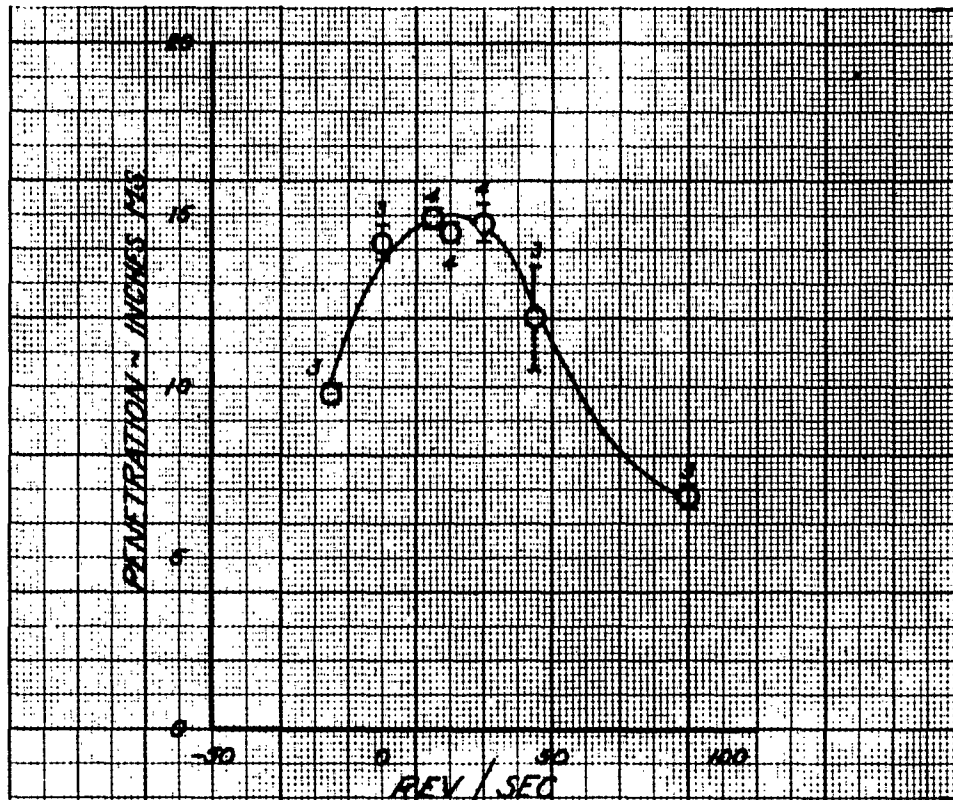


Fig. 4. Penetration Versus Spin Rate.
For DRD 254 No. 1 Liners (100 Flat Flutes).

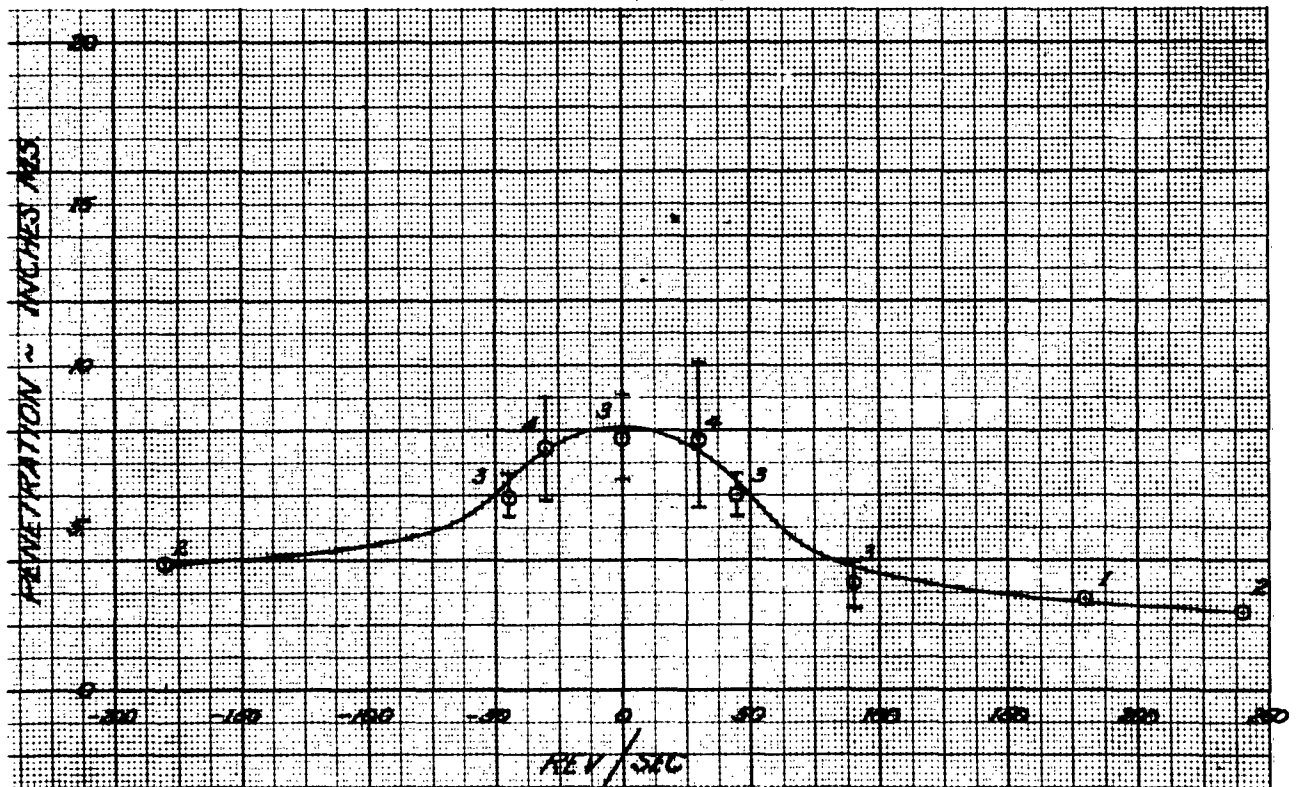


Fig. 5. Penetration Versus Spin Rate.
For DRD 263-1 Liners (4 Curved Flutes).

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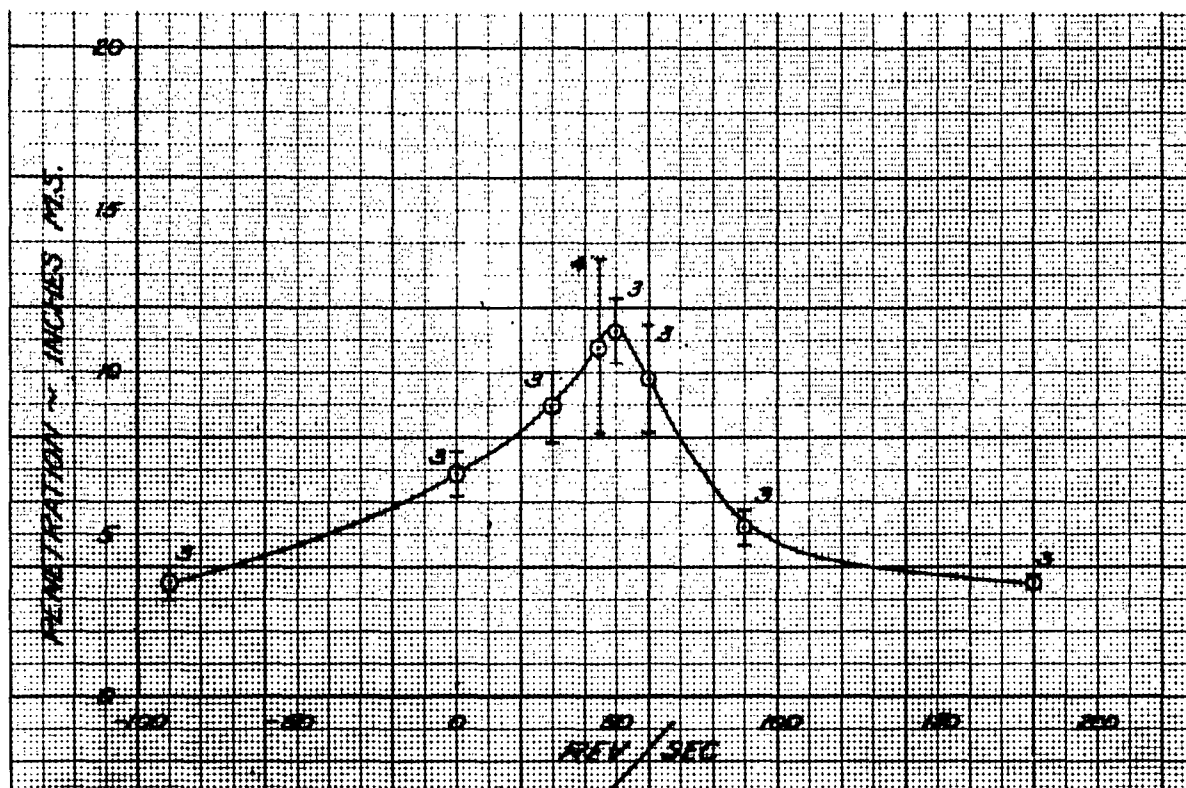


Fig. 6. Penetration Versus Spin Rate.
For DRD 272 No. 1 Liners (50 Flat Flutes).

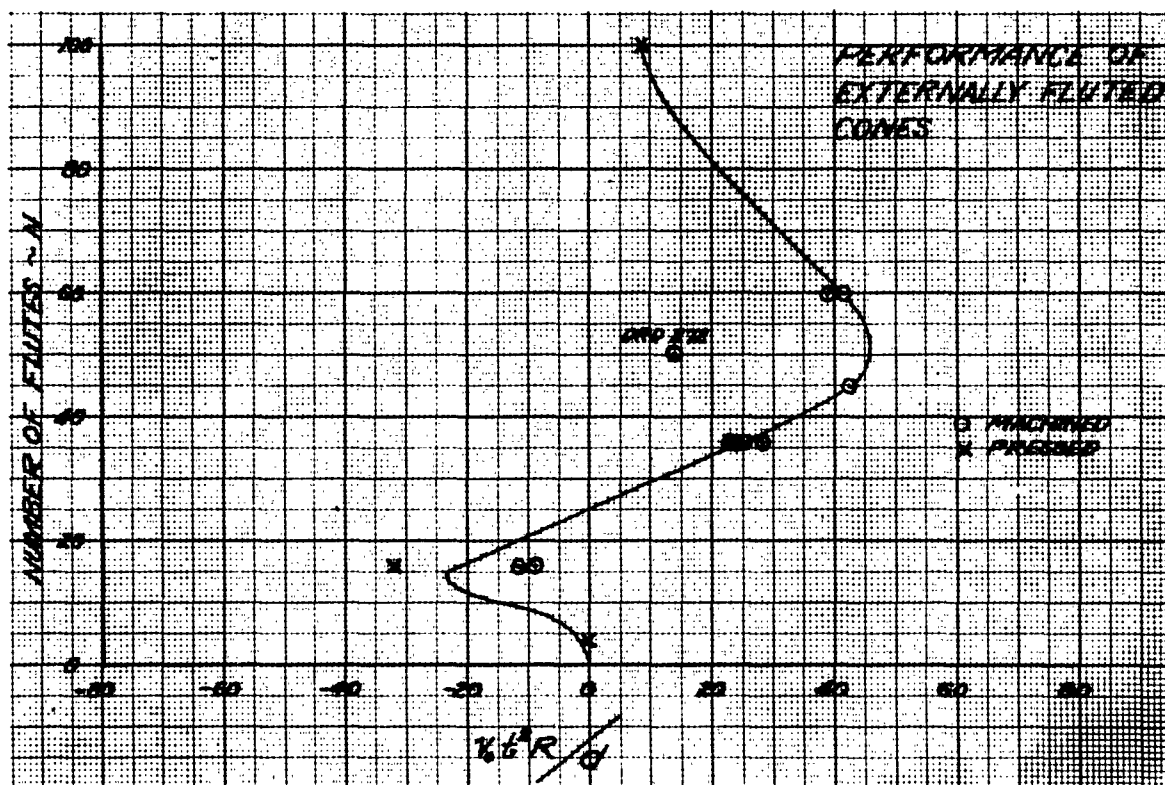


Fig. 7. Performance of Externally Fluted Cones.

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